This presentation premiered at WaterSmart Innovations

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How much Water, Energy and Time are Wasted Waiting for Hot Water to Arrive?

Water Smart Innovations 2010

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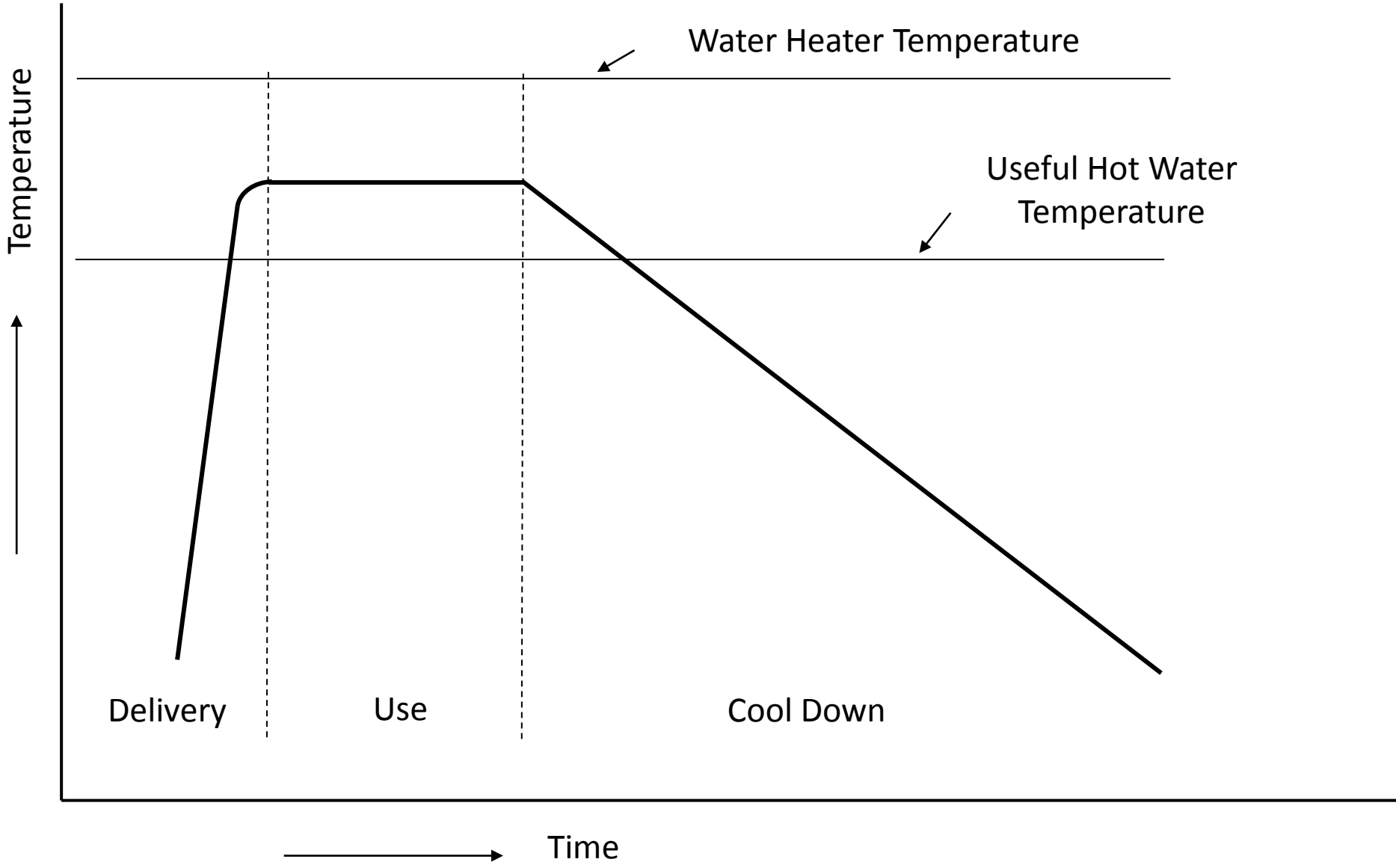
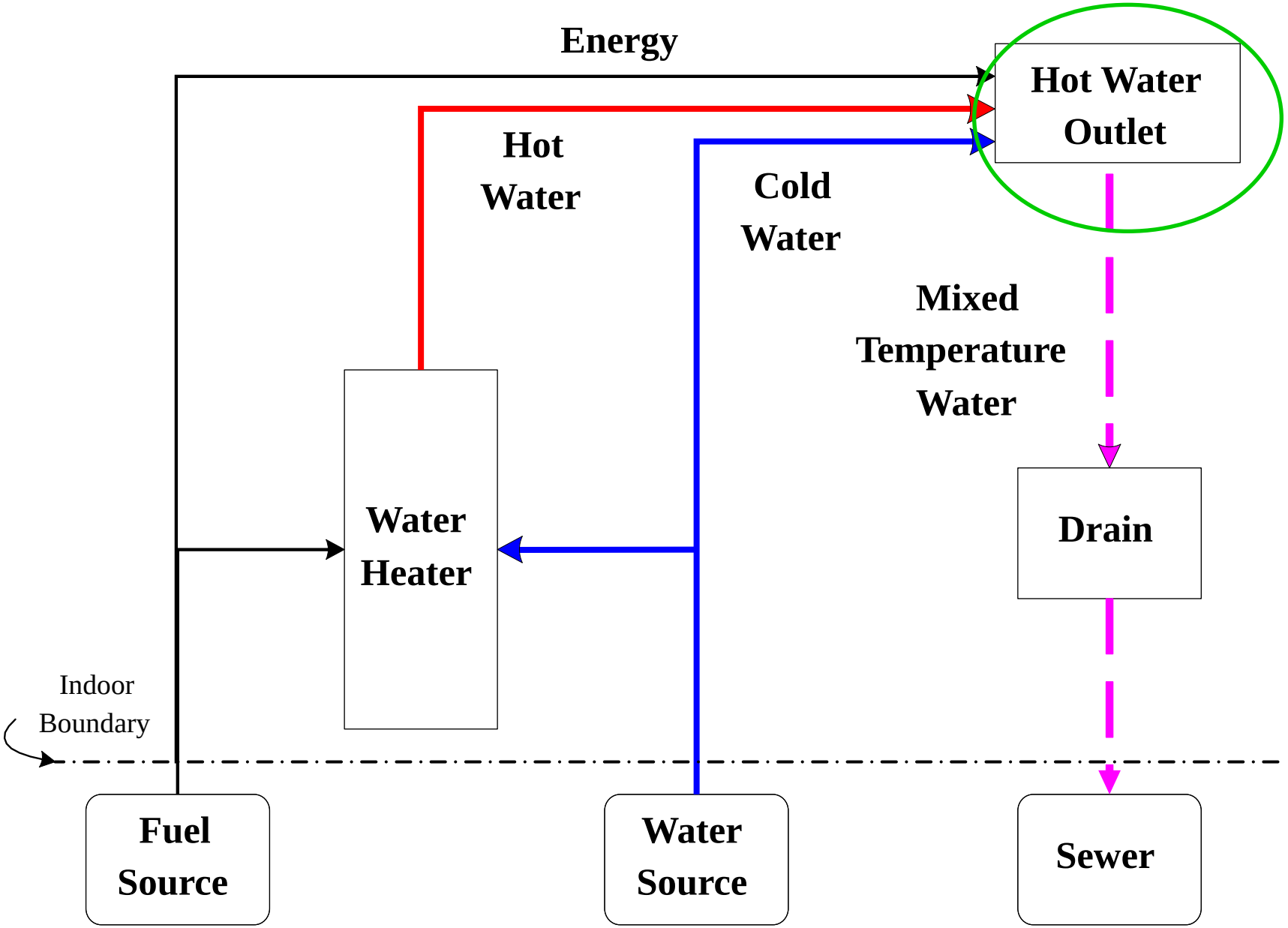
Typical Hot Water Event



Typical “Simple” Hot Water System



Hot Water Outlet Flow Rates

Maximum allowable flow rates allowed by Federal and California regulation:

- Shower heads: 2.5 gpm @ 80 psi
- Lavatory and kitchen faucets: 2.2 gpm @ 60 psi
- Replacement aerators: 2.2 gpm @ 60 psi
- Commercial Pre-rinse Spray Valves
  - 1.6 gpm @ 60 psi
  - Capable of cleaning 60 plates at not more than 30 seconds per plate

What is the Future of Flow Rates?

Kitchen sinks – 0.5 to 2 gpm (hot only to left, pot fill)

Lavatory sinks – 0.5 gpm (hot only to left)

Showers – 1.5 gpm (water down drain)

Showers – 15 gallons (maximum volume per event)

What impact will these flow rates have on system performance?

Given these flow rates, what impact will the interactions with the rest of the system have on customer satisfaction?

How Much is Hot? How Much is Cold?

- $gpm_{mix} = gpm_{cold} + gpm_{hot}$
- $gpm_{cold} = gpm_{mix} * (T_{hot} - T_{mix})/(T_{hot} - T_{cold})$
- $gpm_{hot} = gpm_{mix} * (T_{mix} - T_{cold})/T_{hot} - T_{cold})$

Example:

- $gpm_{mix} = 2.0$
- $T_{cold} = 50F$
- $T_{hot} = 120F$
- $T_{mix} = 105F$
- gpm_{hot} $= 2*(105-50)/(120-50) = 2*(55)/(70)$
  $= 1.57$ gpm
- gpm_{cold} $= 2.0 – 1.57 = 0.43$

How Much is Hot? How Much is Cold?

Cold Water Temperature (F)	Percent of Mixed Temperature Water (105F) that is Hot										
	Hot Water Temperature (F)										
	110	115	120	125	130	135	140	145	150	155	160
35	93%	88%	82%	78%	74%	70%	67%	64%	61%	58%	56%
40	93%	87%	81%	76%	72%	68%	65%	62%	59%	57%	54%
45	92%	86%	80%	75%	71%	67%	63%	60%	57%	55%	52%
50	92%	85%	79%	73%	69%	65%	61%	58%	55%	52%	50%
55	91%	83%	77%	71%	67%	63%	59%	56%	53%	50%	48%
60	90%	82%	75%	69%	64%	60%	56%	53%	50%	47%	45%
65	89%	80%	73%	67%	62%	57%	53%	50%	47%	44%	42%
70	88%	78%	70%	64%	58%	54%	50%	47%	44%	41%	39%
75	86%	75%	67%	60%	55%	50%	46%	43%	40%	38%	35%
80	83%	71%	63%	56%	50%	45%	42%	38%	36%	33%	31%

How Much is Hot? How Much is Cold?

Cold Water Temperature (F)	Percent of Mixed Temperature Water (105F) that is Hot										
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	110	115	120	125	130	135	140	145	150	155	160
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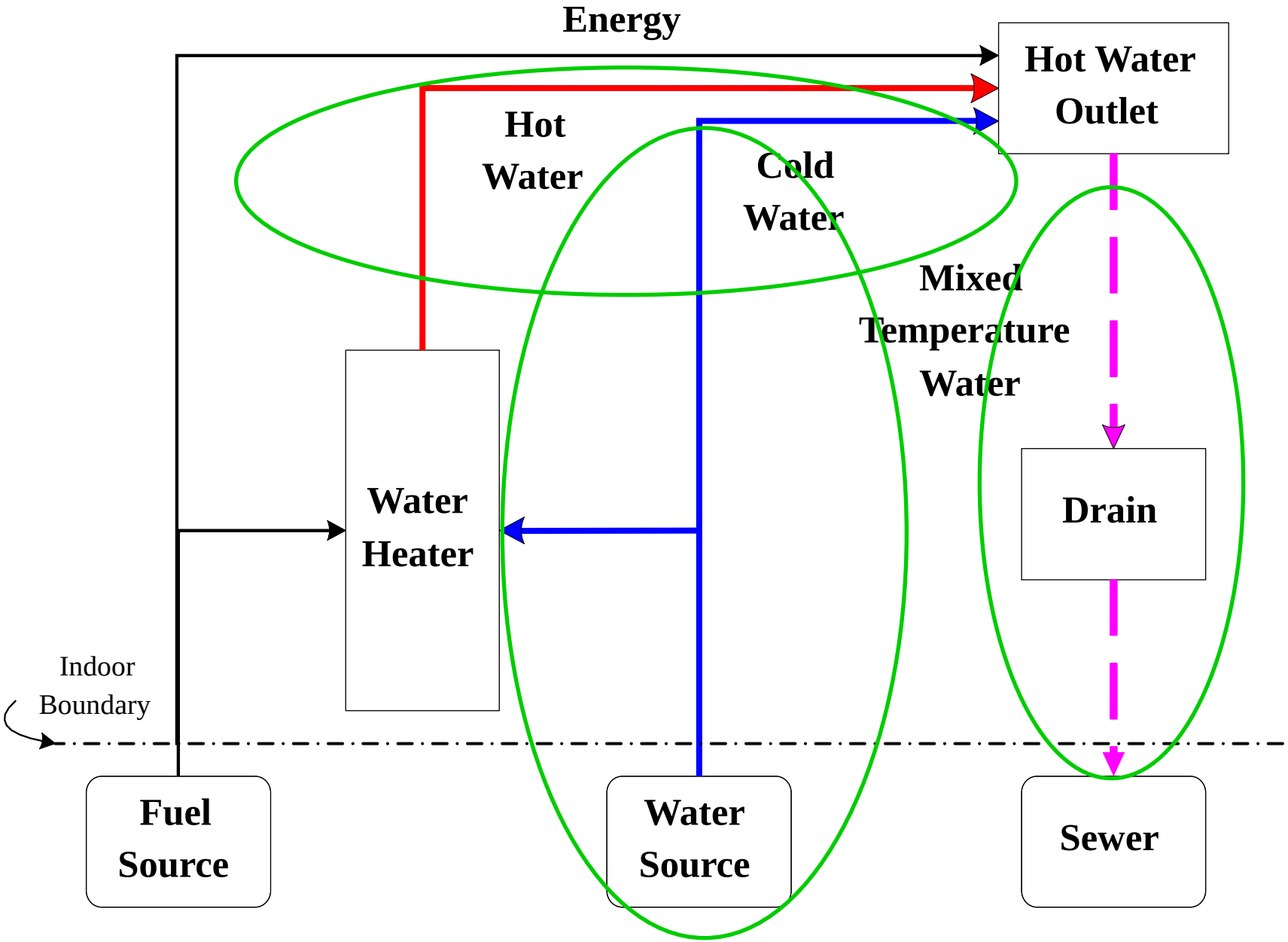
40	93%	87%	81%	76%	72%	68%	65%	62%	59%	57%	54%
45	92%	86%	80%	75%	71%	67%	63%	60%	57%	55%	52%
50	92%	85%	79%	73%	69%	65%	61%	58%	55%	52%	50%
55	91%	83%	77%	71%	67%	63%	59%	56%	53%	50%	48%
60	90%	82%	75%	69%	64%	60%	56%	53%	50%	47%	45%
65	89%	80%	73%	67%	62%	57%	53%	50%	47%	44%	42%
70	88%	78%	70%	64%	58%	54%	50%	47%	44%	41%	39%
75	86%	75%	67%	60%	55%	50%	46%	43%	40%	38%	35%
80	83%	71%	63%	56%	50%	45%	42%	38%	36%	33%	31%

Typical “Simple” Hot Water System



Hot Water Distribution Systems

Definitions

1. A Twig line serves one hot water outlet.
   - The diameter of the twig should be determined by the flow rate of the outlet or appliance it serves and the pressure drop that will occur due to length, velocity and restrictions to flow (e.g. elbows and tees).
2. A Branch line serves more than one.
3. A Trunk line serves many.
4. A Main line serves the building.

The Ideal
Hot Water Distribution System

- Has the smallest volume (length and smallest "possible" diameter) of pipe from the source of hot water to the hot water outlet.
- Sometimes the source of hot water is the water heater, sometimes a trunk line.
- For a given layout (floor plan) of hot water locations the system will have:
  - The shortest buildable trunk line
  - Few or no branches
  - The shortest buildable twigs
  - The fewest plumbing restrictions
  - Insulation on all hot water pipes, minimum R-4

To Improve the Delivery Phase:

Get hotter water sooner by
minimizing the waste of water, energy & time

- Reduce the volume of water in the pipe
  - Smaller diameter, shorter length
  - As flow rates go down, water waste goes up
- Reduce the number of restrictions to flow
  - Decrease “effective length”
- Increase the flow rate
  - Prime the hot water trunk just prior to use with a demand-controlled pump
- Insulate the pipe
  - Becomes critical for very low flow rates and adverse environmental conditions

Water Waste as a Function of Flow Rate (Really Velocity)

Flow Rate	¾ inch Nominal Diameter Pipe	
	Relative Water Waste Percent	Approximate Velocity Feet per Second
Greater than 4 gpm	Just over 100%	Greater than 3
4 gpm	110%	2.65
3 gpm	120%	1.99
2 gpm	130%	1.33
1 gpm	150%	0.66
0.5 gpm	Roughly 200%	0.33
0.25 gpm	????	0.17

The velocity of 0.5 gpm in ¾ inch nominal pipe
is roughly equivalent to the velocity of
2 gpm in 1.5 inch nominal pipe

Length of Pipe that Holds 8 oz of Water

	3/8" CTS	1/2" CTS	3/4" CTS	1" CTS
	ft/cup	ft/cup	ft/cup	ft/cup
"K" copper	9.48	5.52	2.76	1.55
"L" copper	7.92	5.16	2.49	1.46
"M" copper	7.57	4.73	2.33	1.38
CPVC	N/A	6.41	3.00	1.81
PEX	12.09	6.62	3.34	2.02
Ave	**8 feet**	**5 feet**	**2.5 feet**	**1.5 feet**

Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Flow Rate (GPM)	Time Until Hot Water Arrives (Seconds)															
	1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60
0.5	0.01	0.02	0.03	0.03	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50
1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	1.17	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	0.83	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
5.5	0.09	0.18	0.28	0.37	0.46	0.92	1.38	1.83	2.29	2.75	3.21	3.67	4.13	4.58	5.04	5.50
6	0.10	0.20	0.30	0.40	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
7	0.12	0.23	0.35	0.47	0.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	6.42	7.00
7.5	0.13	0.25	0.38	0.50	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50
8	0.13	0.27	0.40	0.53	0.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
8.5	0.14	0.28	0.43	0.57	0.71	1.42	2.13	2.83	3.54	4.25	4.96	5.67	6.38	7.08	7.79	8.50
9	0.15	0.30	0.45	0.60	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00
9.5	0.16	0.32	0.48	0.63	0.79	1.58	2.38	3.17	3.96	4.75	5.54	6.33	7.13	7.92	8.71	9.50
10	0.17	0.33	0.50	0.67	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.00

1 cup = 8 ounces = 1/16th gallon = 0.0625 gallon

Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Flow Rate (GPM) \ Time Until Hot Water Arrives (Seconds)	1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60
0.5	0.01	0.02	0.03	0.03	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50
1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	1.17	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	0.83	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
5.5	0.09	0.18	0.28	0.37	0.46	0.92	1.38	1.83	2.29	2.75	3.21	3.67	4.13	4.58	5.04	5.50
6	0.10	0.20	0.30	0.40	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
7	0.12	0.23	0.35	0.47	0.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	6.42	7.00
7.5	0.13	0.25	0.38	0.50	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50
8	0.13	0.27	0.40	0.53	0.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
8.5	0.14	0.28	0.43	0.57	0.71	1.42	2.13	2.83	3.54	4.25	4.96	5.67	6.38	7.08	7.79	8.50
9	0.15	0.30	0.45	0.60	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00
9.5	0.16	0.32	0.48	0.63	0.79	1.58	2.38	3.17	3.96	4.75	5.54	6.33	7.13	7.92	8.71	9.50
10	0.17	0.33	0.50	0.67	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.00

1 cup = 8 ounces = 1/16th gallon = 0.0625 gallon

Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Flow Rate (GPM) \ Time Until Hot Water Arrives (Seconds)	1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60
0.5	0.01	0.02	0.03	0.03	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50
1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	[illegible]	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	[illegible]	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	0.83	1.04	1.25	1.46	[illegible]	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	[illegible]	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
5.5	0.09	0.18	0.28	0.37	0.46	0.92	1.38	1.83	2.29	2.75	3.21	3.67	4.13	4.58	5.04	5.50
6	0.10	0.20	0.30	0.40	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
7	0.12	0.23	0.35	0.47	0.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	6.42	7.00
7.5	0.13	0.25	0.38	0.50	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50
8	0.13	0.27	0.40	0.53	0.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
8.5	0.14	0.28	0.43	0.57	0.71	1.42	2.13	2.83	3.54	4.25	4.96	5.67	6.38	7.08	7.79	8.50
9	0.15	0.30	0.45	0.60	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00
9.5	0.16	0.32	0.48	0.63	0.79	1.58	2.38	3.17	3.96	4.75	5.54	6.33	7.13	7.92	8.71	9.50
10	0.17	0.33	0.50	0.67	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.00

1 cup = 8 ounces = 1/16th gallon = 0.0625 gallon

What About *Really* Low Flow Rates?

Volume is Critical when Flow Rates are Low

- For all cold-start hot water events
  - the waste of water and energy goes up as flow rate goes down
  - this is exponential compared to the difference in flow rate.
- At flow rates of 0.5 gpm and less (think the portion of hot water in hands-free lavatory faucets, or about 0.25 gpm)
  - the total volume that runs down the drain before the hot water arrives can be 2-4 times the volume of not-hot-enough water that is in the piping at the start of the draw.

Is Volume or Time the Limiting Factor?

- It may make more sense to base the volume at these low flow rates on the time-to-tap.
  - ASPE says that up to 10 seconds is acceptable. To meet this requirement this means that:
    - At 2 gpm, the volume can be no more than 4 cups
    - At 1 gpm, the volume can be no more than 2 cups
    - At 0.5 gpm, the volume can be no more than 1/2 cup
    - At 0.25 gpm, the volume can be no more than 1/6 cup
  - *Volumes above are approximate.*
  - *These volumes include the volume in the piping and in the fixture itself.*

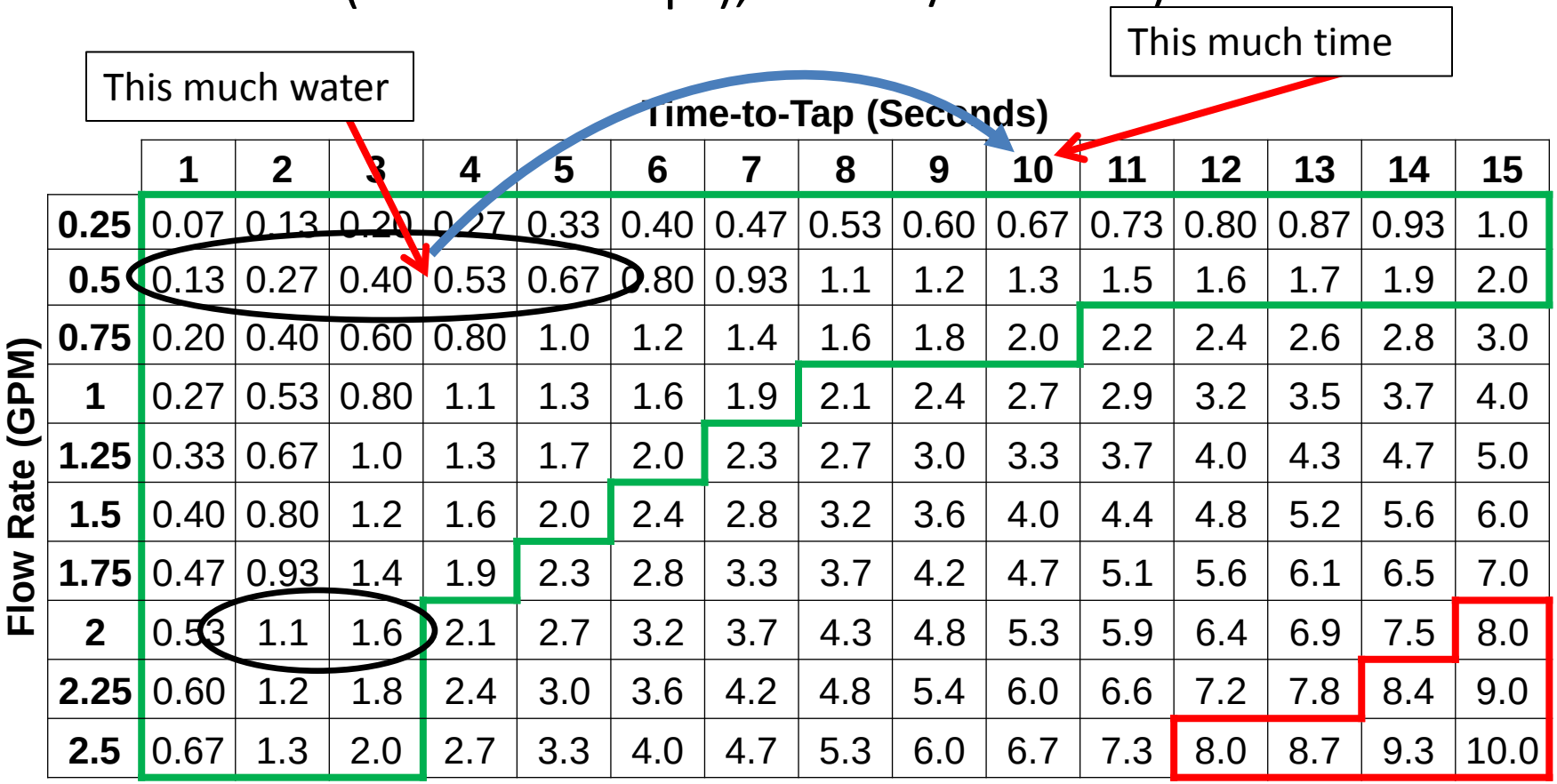
Cups Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Flow Rate (GPM) \ Time-to-Tap (Seconds)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.25	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
0.5	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0
0.75	0.20	0.40	0.60	0.80	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1	0.27	0.53	0.80	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
1.25	0.33	0.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0
1.5	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
1.75	0.47	0.93	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.5	7.0
2	0.53	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0
2.25	0.60	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0
2.5	0.67	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

Cups Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

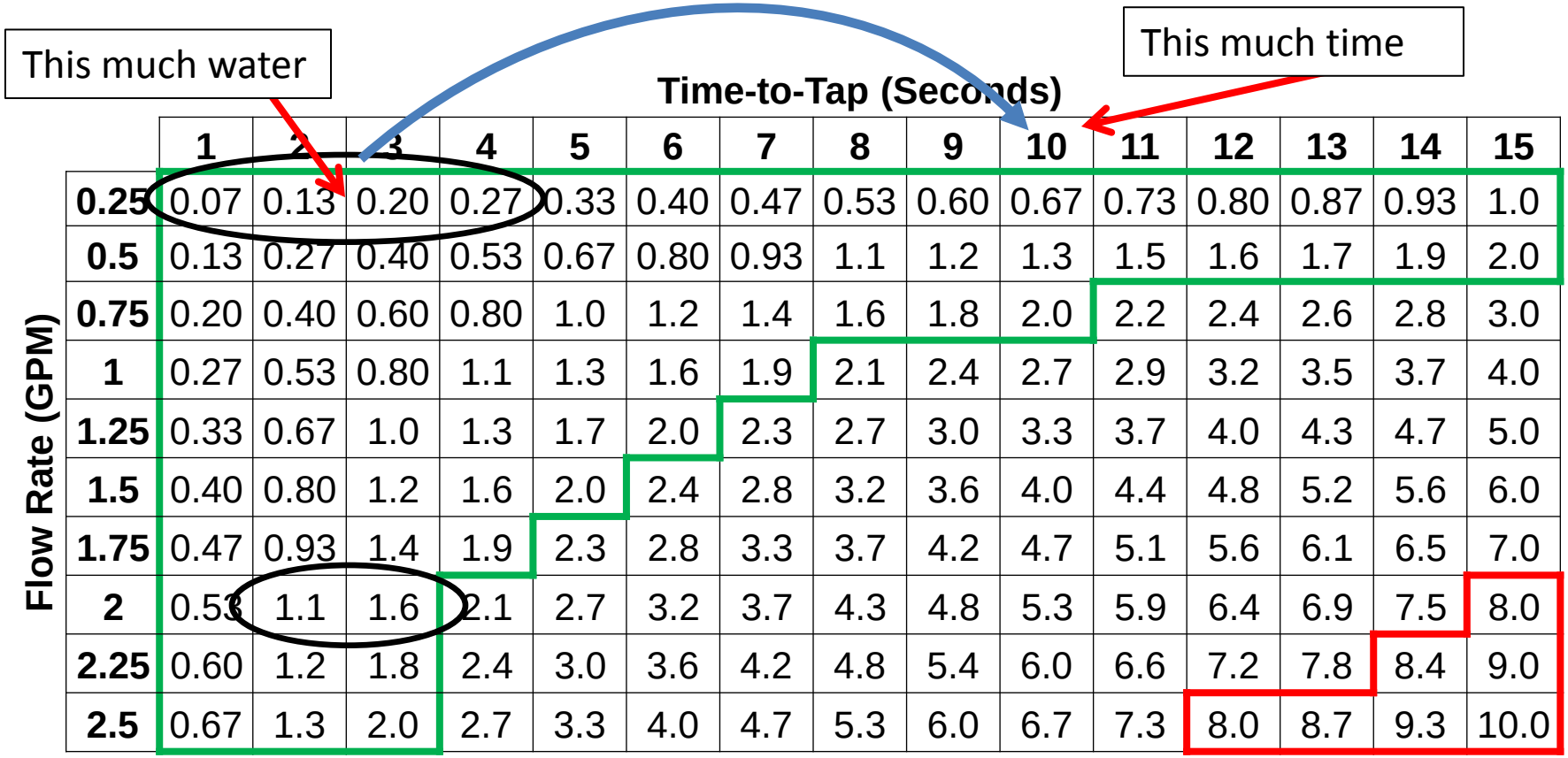


Flow Rate (GPM)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.25	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
0.5	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0
0.75	0.20	0.40	0.60	0.80	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1	0.27	0.53	0.80	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
1.25	0.33	0.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0
1.5	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
1.75	0.47	0.93	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.5	7.0
2	0.53	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0
2.25	0.60	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0
2.5	0.67	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

"Future Proof" the Hot Water Distribution System

Cups Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)



Flow Rate (GPM)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.25	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
0.5	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0
0.75	0.20	0.40	0.60	0.80	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1	0.27	0.53	0.80	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
1.25	0.33	0.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0
1.5	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
1.75	0.47	0.93	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.5	7.0
2	0.53	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0
2.25	0.60	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0
2.5	0.67	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

"Future Proof" the Hot Water Distribution System

What Diameter Pipe Can We Use?

- With 1/2 nominal tubing (UPC minimum)
  - 1.5 cups = 9 feet in PEX
  - 1/2 cup = 3 feet in PEX
  - 1/6 cup = 1 feet in PEX
- With 3/8 inch nominal tubing (IPC minimum)
  - 1.5 cups = 18 feet in PEX
  - 1/2 cup = 6 feet in PEX
  - 1/6 cup = 2 feet in PEX
- With 1/4 inch nominal tubing
  - This diameter is used in the exposed piping under sinks today. It is not currently covered in either code for use behind the wall, but could be specified based on physics
    - 1.5 cups = 36 feet in PEX
    - 1/2 cup = 12 feet in PEX
    - 1/6 cup = 4 feet in PEX

The length in copper or CPVC will be less

Options

- It appears to be difficult to expect the use of ¼ inch nominal tubing in the near future.

1. Allow for a longer time-to-tap for these low fixture flow rates.
    - Probably unacceptable because duration of actual use is small and wait time is a large percentage of the total hot water event.
2. Run circulation loops and heat traced lines down the wall behind lavatory sinks.
    - Adds 16-20 feet of large diameter pipe, 4 elbows, insulation and labor costs for every bathroom group

Options – Continued

3. Install water heaters in each bathroom
   - Takes the low flow fixtures off the main system.
     - This saves the cost of the additional piping to provide the desired level of performance.
   - Adds the cost of one or more water heaters per bathroom group.
     - Could be as many as one tankless electric water heater per sink, but this is actually excessive.
     - Could be as few as one water heater for back-to-back banks of lavatory faucets.
     - Water heater must be able to operate with a flow rate of 0.25 gpm
   - Adds the cost of operation and maintenance of these water heaters.
   - In larger bathrooms with many lavatory sinks, could combine one water heater with an on-demand priming system.
     - Reduces the number of water heaters while providing the desired level of performance.

Options – Continued

4. Heat trace all of the run-outs from a circulation loop or heat traced line to just behind the wall near the angle stop.
    - Adds cost for installation and operation of heat trace system. Trades off increased energy use for water savings.
5. Install on-demand pumping systems on the run-outs from a circulation loop or heat traced line
    - Prime the branch line behind the wall with hot water when someone enters the restroom.
    - Adds cost for installation of the on-demand pump, activation mechanism and controls
    - Some small energy cost to prime the line with hot water. Less than would have been spent running the water down the drain. Less than standard recirculation or heat trace.